

Energy Use Benchmarks and BEARS Scale

Overview

The BEARS rating will be determined by comparing a Rated Building to an energy benchmark. As noted in the report **4.2 Framework for Building Categories and Benchmark Approach**, static benchmarks are set for each BEARS building type in each climate zone. This document summarizes the Benchmark Buildings and their energy simulation results. Additionally, this document summarizes the development of the Rating Scale and the process used to calculate a BEARS rating for a Rated Building.

Benchmark Building Specifications

The Benchmark Buildings are EnergyPlus simulation models for each BEARS building type in each California climate zone. The U.S. Department of Energy (DOE) commercial prototype models were used as the basis for the BEARS Benchmark Buildings as noted in the report **4.2 Framework for Building Categories and Benchmark Approach**. Parameters for the DOE prototype models were modified to match the prescriptive requirements of Title 24, 2008. Where prescriptive requirements did not exist (e.g. receptacle loads or other process loads), parameters were set to match those in the DOE prototype models. Similarly, operational defaults such as operating hours and equipment schedules are based on the Title 24 prescribed values when available; otherwise, DOE prototype data was used.

The report **4.2** provides a summary of the BEARS building type categories and a mapping to the appropriate DOE prototype building model type. In some cases new or modified versions of the prototype models are necessary to capture properties of the BEARS buildings that were not adequately represented by the prototype models.

Documentation of the Benchmark Buildings will consist of whole building energy model input files, uploaded to NREL's Building Component Library (bcl.nrel.gov) website or another appropriate public website determined by the Energy Commission. Input summary tables are also provided in **Appendix 1: BEARS Benchmarks Input Summary.xls**. These tables provide a detailed summary of the model input parameters used to define the Benchmark Building for each building category.

Benchmark Building Energy Results

For each BEARS building type, a set of benchmark energy use data was calculated by simulating the appropriate BEARS prototype model. The energy results include site energy and TDV energy broken down by fuel type, and end use breakdowns (such as lighting, heating, cooling, etc.) for each climate zone and building type. Additionally, Energy Use Intensity (EUI) metrics are calculated to quantify energy consumption per square foot of building area. The energy use data for each Benchmark Building and climate zone is provided in **Appendix 2: Bears Benchmarks Outputs Summary.xls**.

BEARS Rating Scale Development

The rating scale is a means to “grade” a Rated Building’s energy efficiency potential based on its assets. The scale will convey meaningful information about the building’s energy performance and provide a comparative assessment of the building compared to buildings of a similar type. It will also function as a means to track a building’s progress towards longer term energy policy goals. The BEARS program will communicate this energy

efficiency potential by using a scale that indicates relative performance rather than absolute energy metrics such as kWh or kBtu.

Objectives of the Rating

The asset rating is designed to achieve the following objectives:

1. Rate the inherent energy efficiency of the commercial building's envelope and system design relative to code and existing commercial building stock;
2. Provide a metric relating to the financial implications of a building's energy efficiency;
3. Communicate the importance of zero net energy buildings as a reference point for California's energy policy;
4. Communicate a building's potential for an improved asset rating relative to other buildings of similar type and location;
5. Apply across the widest possible range of building types and sizes; and
6. Be a reasonably priced rating for building owners to obtain.

Defining the Scale

The steps for developing the rating scale are as follows:

1. **Choose an energy metric** that represents a building's annual energy consumption.
 - a. The energy metric can be site energy, source energy, energy cost or TDV.
 - b. Because the asset rating represents the whole building performance, the energy use metric should account for all of the building's systems, not just those that utilize regulated energy.
2. **Define a numerical scale** that can cover the full range of building performance, from older buildings that are much less efficient than the current energy code or the stock median, to buildings that are net-zero or net energy producers.
3. **Define what the benchmark (normalizing value) represents on the scale.** The benchmark may be based on average building energy use for a typical vintage of building, the code minimum, or some other set of baseline data.
4. **Define a high and a low point of the scale.** The high point can represent a highest performing building by today's available technology or it can represent zero net energy. The low point may represent the energy consumption of a very poor building. Alternately, no low point may be set to allow for a full range of assessments without setting an arbitrary bottom end of the scale.
5. **Optional: Define rules to map rating to categorical scale.** If determined to be important for communicating a rating, provide a means to map a building rating on the scale with a letter grade or other indicator that may be more intuitive to a consumer.
6. **Consider providing a common scale** for both asset ratings and operational ratings. This will help bridge the gap between predicted performance through models and actual performance.

Energy Metrics

There are several energy metrics that could be used to calculate a building's energy performance rating: site energy, source energy, energy cost or time dependent valuation (TDV). These metrics are defined as follows:

- **Site Energy:** Site energy measures the amount of energy consumed at a facility—a number that is reflected on gas and electric utility meters, and on meters attached to any onsite renewable sources.
- **Source Energy:** Source energy includes site energy consumed at the building and also includes energy used offsite to generate and transport the energy that is used at the building. The calculation of source energy typically involves multiplying the site energy by a source conversion factor.

- **Energy Cost:** Energy cost simply measures what a building operator is paying for energy. This definition uses market valuation to account for the relative value of various fuels.¹
- **Time Dependent Valuation:** TDV values energy differently depending on the time it is used. This means that electricity saved on a hot summer afternoon will be worth more than the same amount of electricity saved on a winter morning. The value assigned to energy savings through TDV more closely reflects the market for electricity, gas, propane and other energy sources and provides incentives for measures, such as thermal storage or daylighting, that are more effective during peak periods.

Site Energy is an intuitive metric to understand because it may be directly read on an energy meter, and is documented on a consumer's utility bills. A limitation of site energy is that it does not account for the value of different fuel sources. For example, when comparing a building with natural gas heating to a building with electric heating, they may require the same number of BTUs for heating but the electric heated building will be more expensive to operate.

Energy Star uses source energy, which is a good metric for the total energy consumption of the building, accounting for different generation and transmission costs associated with electricity, natural gas, and other fuel sources. However, source energy cannot capture other usage factors that impact customers through time-of-use and demand charges.

Energy cost is a metric used by ASHRAE 90.1 Appendix G, programs such as LEED, and the Commercial Energy Services Network (COMNET). In some cases, regional factors or average rates are used for converting energy use to costs, and these approaches do not reflect the local and fluid energy market within the state of California. More accurate energy cost estimates can be calculated by using detailed utility rate structures, however since rate structures can vary from building to building, it may be difficult to compare multiple buildings' performance with this metric.

Time dependent valuation (TDV) of energy remains the most comprehensive means of accounting for energy costs from both the consumer and societal perspective. It is used in California for both performance-based code analysis and utility incentive programs. Hourly factors estimate the value of electricity, gas and other sources, based on the expected costs of running power plants and other generation sources at that time. As a result, energy is valued more highly during times of peak demand, since less efficient plants must be run to meet the marginal load. Therefore, efficiency measures such as cool roofs and load shifting measures such as thermal energy storage have a greater benefit since they reduce demand and reduce energy use during peak periods.

The TDV metric more closely reflects the value of energy than source energy or other metrics, and it may be consistently applied across every building type. Since the asset rating will likely be used as a measure of the building's valuation, it is recommended to use TDV as the metric to account for these factors. The metric will be reported in terms of TDV energy per square foot of building area. This metric is TDV energy use intensity (EUI) and will allow buildings of different sizes to be compared to each other.

The TDV factors are updated every Title 24 code cycle to reflect the changing mix of energy sources, California's renewable portfolio standard, and other industry drivers. However, in order to achieve a static benchmark, it is recommended that the current TDV factors are used for the BEARS program so that the rating system is stable over time. If the TDV factors were to be updated at each code cycle, then BEARS ratings would need to be updated each time which may be inconvenient or costly to building owners. Updating the TDV factors could be reassessed in the future, but should be done with caution and clear direction on how to update older BEARS

¹ Source: <http://www.buildinggreen.com/auth/article.cfm/2011/4/29/Measuring-Energy-Use-in-Buildings-Do-Our-Metrics-Really-Add-Up/>

ratings. It may be advisable to only change the TDV factors if there is significant update to the BEARS rating methodology that would necessitate rerating all buildings.

Numerical Scale

The BEARS program recommends using the zero energy performance index (zEPI) scale for indicating energy performance. This scale sets the Benchmark Building score to a value of 100. Zero on the scale indicates zero net energy. Net energy producers could achieve a negative score, while poor performing buildings could be well above 100 on the scale. A score above or below the 100 point can be used to gauge relative performance. For example a score of 80 indicates that the energy consumption is 20% less than the benchmark. A score of 120 indicates the consumption is 20% greater than the benchmark. A key advantage of this scale is that the rating has a linear correlation to energy consumption.

The zEPI scale includes all energy loads of the building, not just regulated loads. The concept of percent savings beyond code that has been used for many years for code compliance or incentive programs can be misleading because it only considers regulated loads as a basis for comparison. While this approach may make sense for assessing a building's energy budget with respect to the energy code, it does not adequately account for a whole building's energy performance and therefore does not give a true assessment of the building's efficiency potential.

An alternate scale that was reviewed is the EnergyStar scale, which relies on the CBECS database for its benchmarking system. In this system, the building energy use is adjusted for neutral variables that depend upon building operations such as number of occupants or operating hours, and compared against a statistical average for a given building type. The scale is a percentile scale and ranges from 1 to 100, with the median 50 indicating that the building performance matches exactly 50% of the buildings with similar characteristics.

However, this system is not recommended due to several limitations:

- 1) Unlike the linear ZEPI scale, there is no direct correlation between the rating and energy use. The rating depends upon the distribution of buildings that fall into different performance bins. For example, a building with a rating of 5 could vastly outperform a building with a score of 2, but would not show much improvement on the scale.
- 2) High performing buildings are not adequately rated on this scale. To meet an Energy Star score of 99, a building might only need to be 50% better than the median. Further improvements in efficiency for ultra-low energy or even net-zero buildings would not register any improvement on the scale – they would still have a 99 score. In this sense, the high end of the scale is “compressed” and does not reflect measures that separate ultra-low energy buildings from high performance buildings.
- 3) The rating scale is developed from a multivariate regression of a small number of variables that are operational characteristics, rather than assets. Some of these neutral variables (climate, number of occupants, operating hours) will not have the same impact for all buildings. A rating that is based on a modeled building can directly account for these effects and many more. For instance, Energy Star uses heating degree days (HDD) and cooling degree days (CDD) to account for climate, but this does not account for temperature extremes and differences in solar radiation that can impact energy use.

The zEPI scale contains more readily actionable information than the Energy Star scale, since the rating is directly proportional to predicted energy use. It allows for assessments to be performed across the full range of energy efficiency. Moreover, the scale allows policymakers to more easily chart a course towards the state's goal of zero net energy buildings.

Figure 1, below, is a graphical representation of the zEPI scale which may be adapted for the BEARS program.

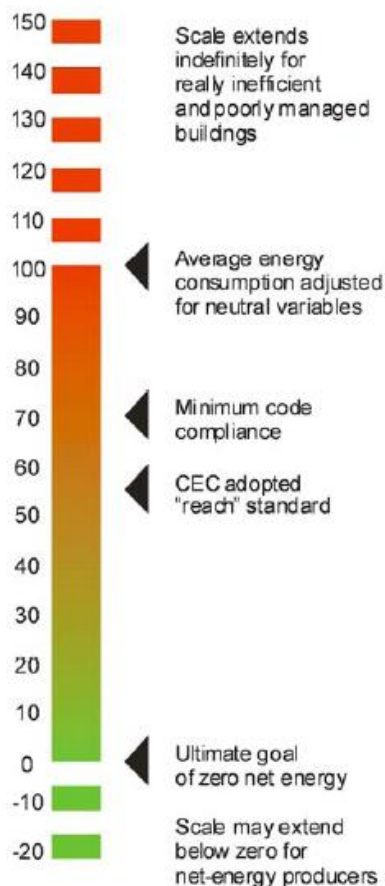


Figure 1 – zEPI: The Recommended Scale

Benchmark

As noted in this report, a benchmark energy use is calculated for each BEARS building type in each California climate zone. The Benchmark Building's simulation inputs are based on Title 24, 2008. The benchmark simulation results are used to determine the 100 point on the zEPI scale. The value is set at 100 because it provides an intuitive assessment of comparable performance as demonstrated by the following examples:

1. A building rated at 100 is the same as the benchmark – it consumes 100% energy compared to the benchmark
2. A building rated at 50 consumes 50% less energy compared to the benchmark
3. A building rated at 150 consumes 50% more energy compared to the benchmark

This benchmark is most useful if it remains stable over time, so that a building that renews its rating can track changes in performance on the scale. It is recommended that the BEARS program uses Title 24, 2008 as a static benchmark. It is recommended that this benchmark be fixed at this value and not be updated to coincide with future Title 24 updates. If the benchmark were to be updated at each code cycle, then BEARS ratings would need to be updated each time which may be inconvenient or costly to building owners. Updating the benchmark could be reassessed in the future, but should be done with caution and clear direction on how to update older BEARS ratings. It may be advisable to only change the benchmarks if there is significant update to the BEARS rating methodology that would necessitate rerating all buildings.

High and Low Points

Since energy use is not a finite quantity, the rating scale can extend indefinitely in either direction. However, reference points are needed for comparison. The benchmark, which corresponds to 100, provides a key reference point, but since it is expected to be based on a fairly recent version of code, it is anticipated that many older buildings will have energy use intensities greater than the 100 point on the scale. For the low point on the scale, 0 is chosen to represent zero net energy, the ultimate goal of California energy policy. A rating that drops below zero would indicate that the rated building is a net energy producer. No high point on the scale is necessary, but one could be set if desired. For example a value of 300 could be set as an upper bound to represent a building with a rated energy efficiency of three times worse than the benchmark.

The concept of a scale where lower (less energy) is better may seem counterintuitive to some consumers, but there is precedent for this type of scale such as the HERS index or the consumer price index. Also, the advantage of setting a low point on the scale to correspond to less energy is that the score directly illustrates a building's energy consumption and the path to net zero: a building rated at 80 is 20% more efficient than a building rated at 100, and a building rated at 0 has reached net zero energy consumption.

Mapping to an Alternate Scoring System

The asset rating could include the numerical rating, and could also include a categorical assignment such as a letter of the alphabet or a discrete number of a particular icon (e.g. the "five star rating"), depending upon the needs for communicating this information to the consumer.

ASHRAE Building EQ program has adopted a rating scale that provides a letter grade assignment for characterizing building energy performance. While this is simple to understand, it is not trivial to determine performance bins to assign to letter grades. A letter grade may also fail to distinguish low energy buildings (close to zero net energy) from high performance buildings. Moreover, a building might make efficiency upgrades that affect its numerical rating but does not impact a letter grade score. This may be a disincentive to owners performing incremental efficiency upgrades.

To develop letter grades, it is necessary to know the distribution of buildings that achieve a specific energy target, such as the percentile scores for Energy Star, which are based on comparisons with CBECS data. It is not recommended that the BEARS program utilize an alphabetical grading system.

Common Scale for Operational Ratings

The development of an Operational Rating scale is outside the scope of this project, however, it is recommended that research be performed to assess the feasibility of using a common scale for both asset and operational ratings. The benefit of a common scale is that it could convey both energy efficiency potential (via the asset rating) and actual energy efficiency (via the operational rating) side by side. This comparison could help identify assets that are good targets for efficiency improvements and operational strategies to improve efficiency. For example, if a building's asset rating is 50 and the operational rating is 75, this may indicate that the building is not being operated in an optimal way.

If the common scale were to be considered, research would need to focus on developing operational benchmarks that can be directly compared to asset benchmarks. Additionally, the operational rating procedure would need to define a way to compare similar building types with significantly different operating schedules.

Calculating the BEARS Rating on the zEPI Scale

The BEARS rating on the zero energy performance index (zEPI) scale can be calculated by the following procedure:

1. Determine the benchmark energy use intensity (EUI) that corresponds to the building type and climate zone of the Rated Building. The resulting number will have units of kTDV/ft²-yr.
2. From an energy simulation, determine the energy use intensity of the Rated Building.
 - a. Rated Building EUI = Annual TDV Energy Use / Gross Floor Area
 - i. The unconditioned floor area and conditioned floor area should be listed, but the gross floor area will be used in EUI calculations. The benchmark may need to be adjusted so that the rated building is neither penalized nor credited for unconditioned floor space. This topic is explored in more detail in the report [4.4 BEARS Software Specification](#).
 - ii. Add annual estimates of energy production (PV or other), in units of kTDV/ft²-yr. Apply TDV hourly profile to convert hourly energy consumption from kWh/ft²-yr and kBtu/ft²-yr to kTDV/ft²-yr. An energy calculator such as the CECPV calculator used for the New Solar Homes Partnership program can be used. The age of the system may need to be accounted for when estimating electricity production. This topic is explored in more detail in the report [4.4 BEARS Software Specification](#).
 - iii. Default assumptions for regulated loads will be used so that they won't affect the rating.
3. Calculate the rating by comparing the Rated Building EUI with the Benchmark EUI:

$$a. \text{ BEARS Rating} = \frac{\text{Rated EUI}}{\text{Benchmark EUI}} * 100$$

- b. Round result to the nearest whole number

Energy simulation results can be highly dependent on the simulation software used. Because the benchmark EUI is calculated using EnergyPlus, it is important that EnergyPlus is also used to calculate the Rated Building's EUI in order to maintain a consistent basis of comparison.

Additional Information to Convey in the Rating

The zEPI scale indicates building energy performance relative to a stable benchmark. Other efficiency targets, such as typical building ratings could also be marked on the scale. The scale also shows a building's progress towards California's policy goal of zero net energy for nonresidential buildings by 2030. A second goal of the asset rating program is to identify the relative energy efficiency of the different end uses of the building. This information does not replace an energy audit; however, it can be used as a screening tool for building owners and facility managers by identifying which end uses have potential to improve a building's efficiency.

One way of representing this information is shown below in figures 2 and 3. The energy use intensity (EUI) of different end uses can be compared between the Rated and Benchmark Buildings. The end use graphs display information familiar to facility managers and building owners.

Figure 4 is an approach to compare the Rated and Benchmark Building end uses in an intuitive manner. Bars in red indicate that an end use in the Rated Building performs worse than the Benchmark Building and identifies an order of magnitude. Bars in green indicate that an end use in the Rated Building performs better than the Benchmark Building and indicates the order of magnitude.

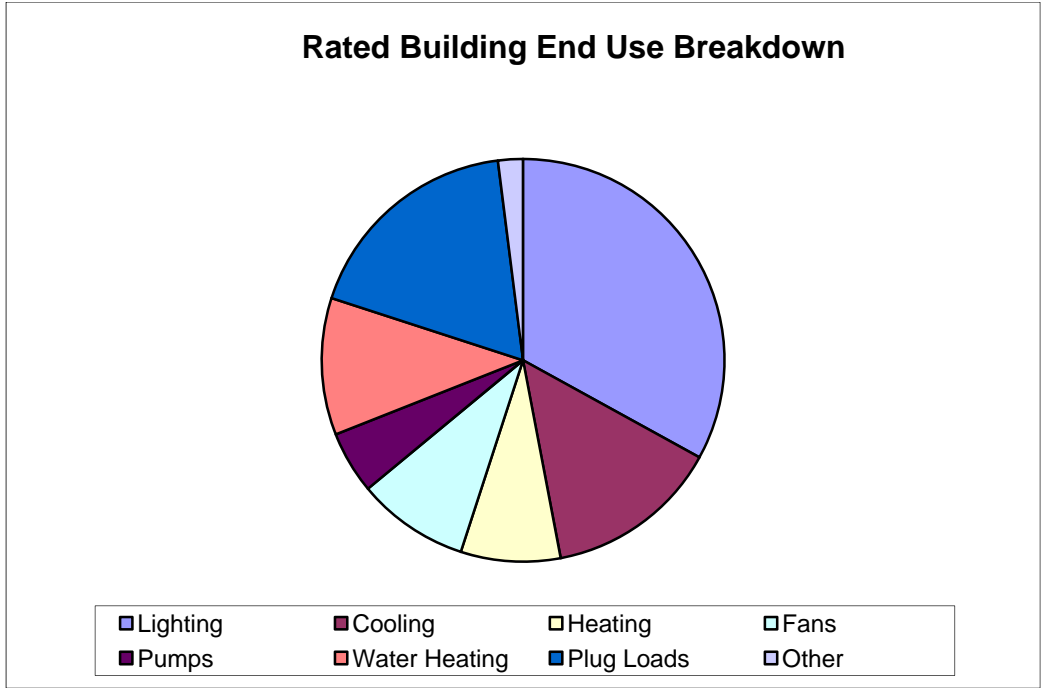


Figure 2 – Rated Building End Use Breakdown

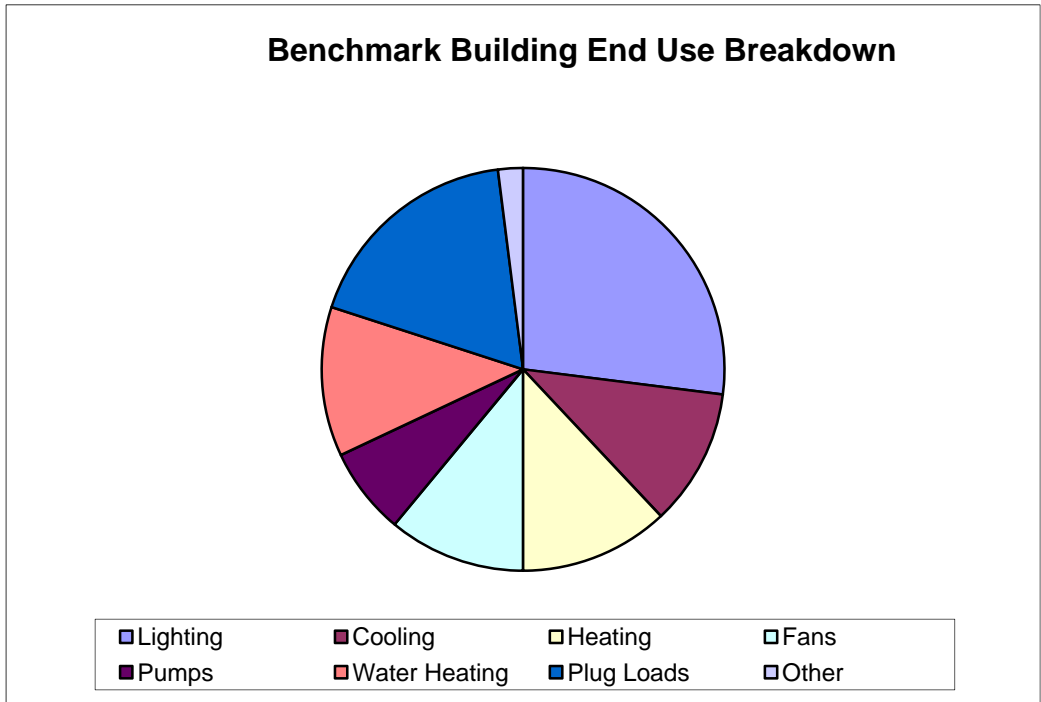


Figure 3 – Benchmark Building End Use Breakdown

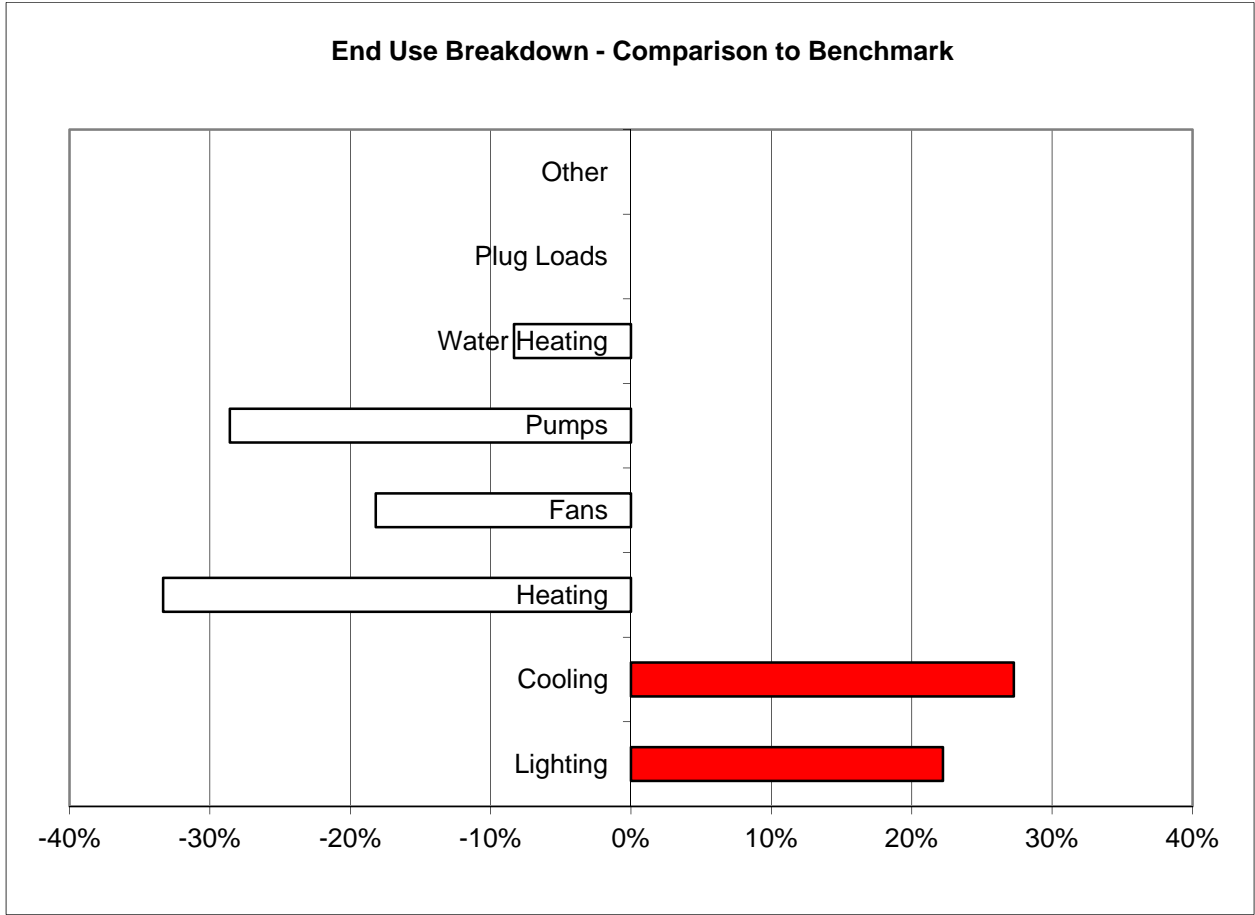


Figure 4 – End Use Efficiency Potential